Science and Technology Investment Report

Major Progress in Key Problem Areas

U.S. Department of Energy
Office of Environmental Management
Office of Science and Technology

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Contents

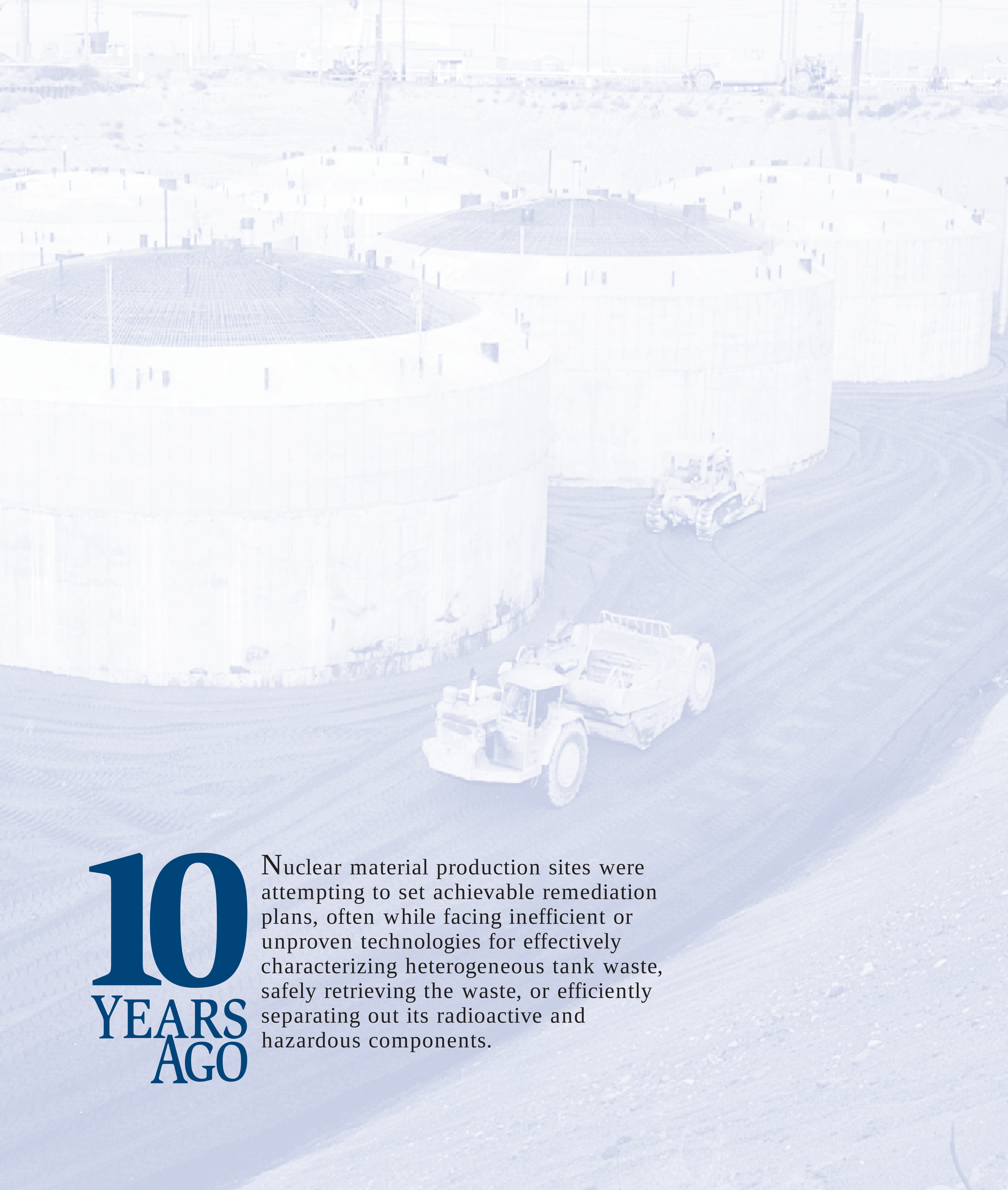
Since its inception ten years ago, the Department of Energy's **Office of Environmental Management** has made significant progress in its ability to clean up the environmental legacy of U.S. nuclear weapon production.

DOE is employing **innovative technologies** to accomplish its mission faster, cheaper, safer, and better. Many of these technologies are available today through the work of the **Office of Science and Technology**.

The innovative technologies featured in this report are making significant contributions to the clean up effort in one or more of the following areas:

- **Cost**–cost savings or cost avoidance
- **Schedule**–acceleration of project schedules
- **Safety**–enhancement of worker safety
- **Risk**–reduction of risk to the public and the environment
- **Performance**–improvement over baseline or enabling what couldn't be done

Tanks Problem Area



10 YEARS AGO

Nuclear material production sites were attempting to set achievable remediation plans, often while facing inefficient or unproven technologies for effectively characterizing heterogeneous tank waste, safely retrieving the waste, or efficiently separating out its radioactive and hazardous components.

TO-DAY

Technology solutions provided by the **Tanks Focus Area** have made major impacts on tank waste retrieval and treatment projects responsible for, leading to improved worker safety, schedule acceleration and substantial projected life-cycle cost avoidance. Overall, EM has demonstrated over 30 tank remediation technologies with over 80 deployments.

Using robotics and advanced mixing and mobilization approaches, highly radioactive tank waste is now being efficiently removed. These new approaches reduce the need for additional liquids, thereby minimizing the waste burden requiring subsequent treatment and disposal—results previously unattainable.

Separations technology has reshaped tank waste processing, enabling key changes in approaches for selectively removing highly radioactive constituents, to greatly reduce liquid waste volume, and chemical constituents, to dramatically reduce the solids volume for subsequent vitrification.

Tomorrow

All major tank sites will be able to characterize tank waste and tank integrity, retrieve and treat waste, and achieve tank closure more cost effectively on or even before baseline schedules. Advances will occur both in current technologies and with the development of solutions founded on scientific research in instrumentation, tank corrosion mechanisms, waste chemistry, separation agents, immobilization, and other important areas.

Tank Waste Retrieval

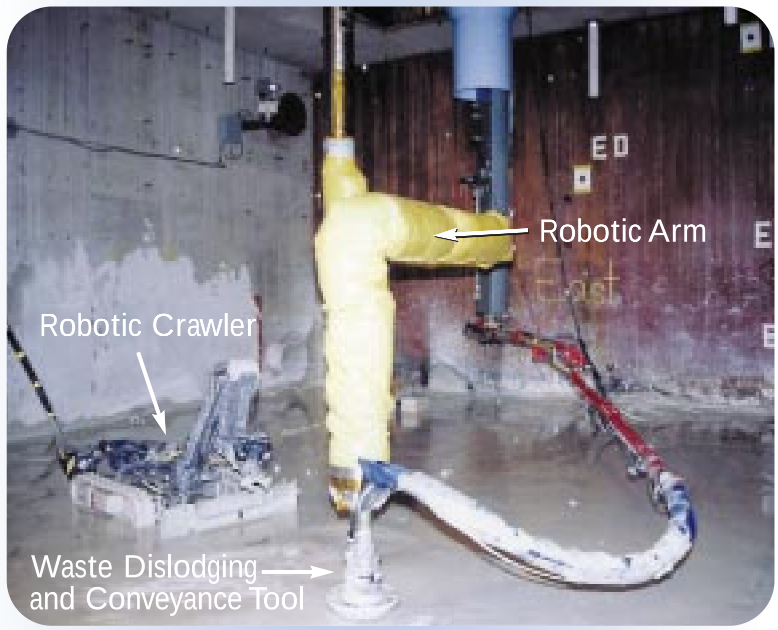
Background

DOE must remediate over 270 underground storage tanks containing almost 100 million gallons of radioactive waste. The tanks' contents and design differ from site to site and tank to tank. The waste types in the tanks include liquids, saltcake, and sludges. Some tanks contain miscellaneous debris, like pipes and chunks of concrete.

Tank waste retrieval devices must fit through small tank openings (risers) and maneuver around internal structures. Retrieval processes must minimize worker exposure and the addition of materials that increase the volume of waste requiring future treatment and disposal.

Integrated Retrieval Systems

Tank waste retrieval technologies are highly effective when combined into systems. At the Gunite and Associated Tanks at the Oak Ridge National Laboratory, a suite of technologies is removing radioactive liquid and sludge and preparing the tanks for closure.



The integrated system used at Oak Ridge:

- Succeeded where earlier sluicing activities had failed to fully clean the tanks.
- Accelerated the schedule and eliminated the costs of continued tank maintenance.
- Reduced downstream costs by minimizing the volume of water added.

[#] indicates technology's OST/TMS ID number.

Robotic Arm with Tool Interface

- Overcomes restricted access problems through risers and around internal structures.
- Safely positions measuring instruments and retrieval tools.
- Minimizes worker exposure.
- Also deployment at Idaho National Environmental Engineering Laboratory.

Safety, Performance

Modified Light-Duty Utility Arm [#40]

Waste Dislodging and Conveyance Tool

Confined Sluicing End Effector [#812]

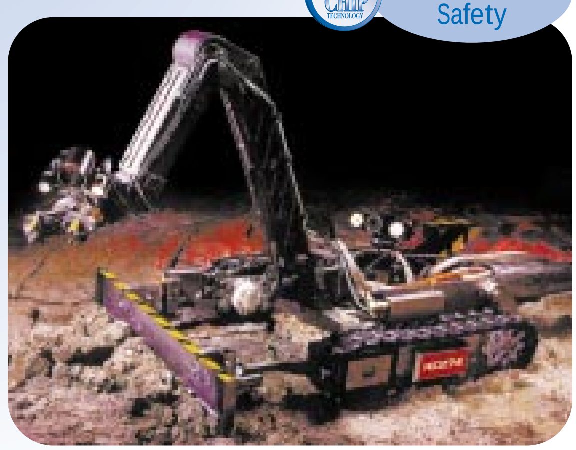
- Easier to manipulate within the tank to remove tank heels.
- Minimizes water additions for conveying waste.

Performance

In-Tank Robotic Crawler

- Fits through small openings in the tank dome and unfolds on tank floor.
- Deploys and positions specialized tools.
- Mobilizes and pushes waste to locations accessible by the robotic arm and waste removal tool.

Performance, Safety



Houdini Remotely Operated Vehicle [#2085]

Waste Separation and High-Level Waste Volume Reduction

Background

DOE tanks contain tens of millions of gallons of highly radioactive liquid along with solid saltcake and sludge. In addition, liquids introduced during retrieval and pretreatment activities increase the volume of waste.

Much of the waste contains significant concentrations of radioactive cesium, which must be removed prior to treatment and disposal. Some nonradioactive chemicals in the sludge interfere with the waste immobilization process.

Chemical reactions can transform liquids into gels and solids that can plug transfer pipes, causing expensive downtime for repairs and increasing the potential for exposure of workers to radioactive materials. These types of problems keep sites from achieving their tank remediation goals.

Solid/Liquid Separation System

Crossflow Filtration [#350]

Performance, Cost

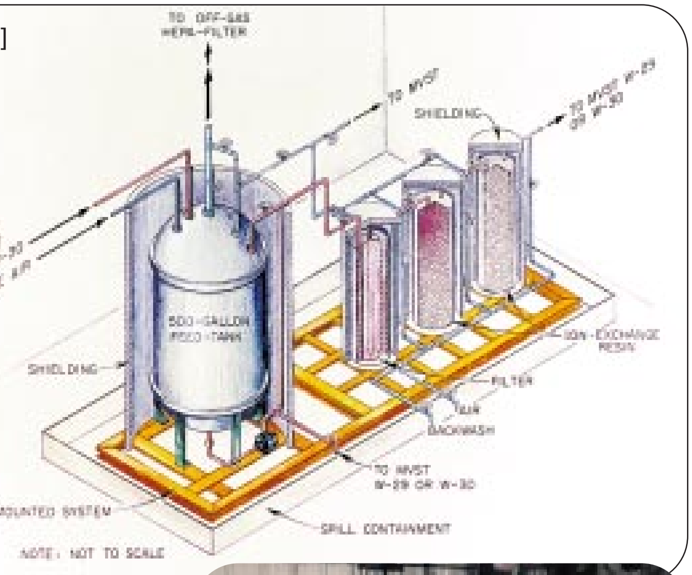
- Much higher throughput and greater reliability than other separation methods.
- Greatly reduces amount of high-activity waste requiring expensive vitrification and disposal.
- Reusable filter cuts waste disposal costs and enhances worker safety.
- Deployed at Oak Ridge National Laboratory and demonstrated using actual waste at the Idaho Nuclear Technology and Engineering Center.

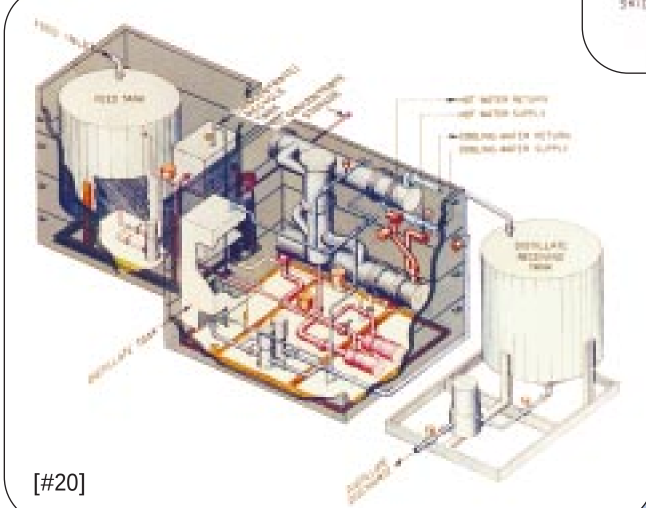
[#] indicates technology's OST/TMS ID number.

Cesium Removal System

- Potential complex-wide cost avoidance of hundreds of millions of dollars.
- Greatly reduces low-activity waste handling and disposal costs.
- Avoids major design and operations costs associated with previous method.
- Deployed at Oak Ridge National Laboratory.

[#21]





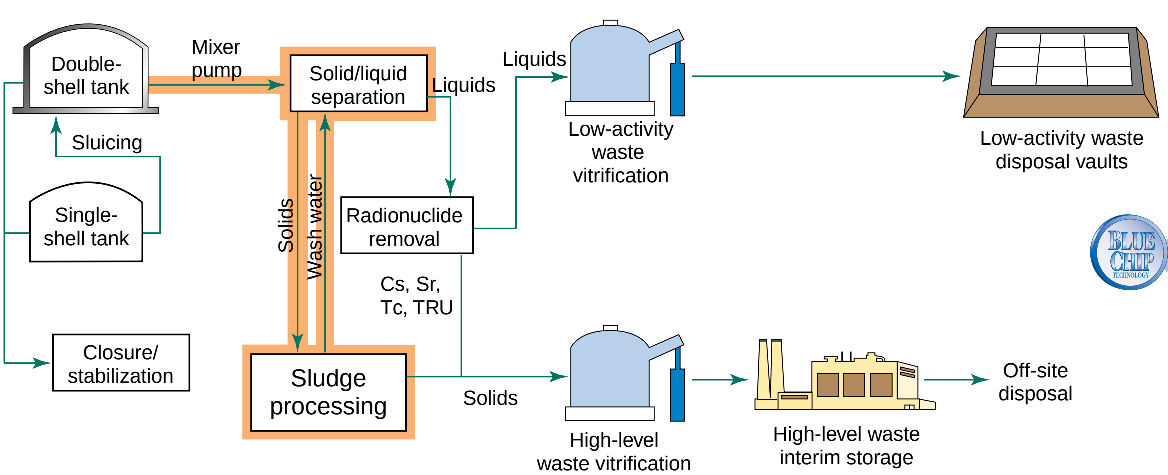
[#20]

Cost

Cesium Removal using Crystalline Silicotitanate (CST) [#21] and Out of Tank Evaporator [#20]

Improved Pretreatment to Reduce High-Level Waste Volume

- Reduces by 60% the volume of Hanford tank sludges requiring expensive treatment and off-site disposal.
- Almost $5 billion in cost avoidance is included in the Hanford baseline from this technology.



Cost, Safety

Enhanced Sludge Washing [#233]

Environmental Restoration Problem Area

10 YEARS AGO

DOE sites had few effective options for addressing subsurface contaminants in soils or groundwater, especially for the most prevalent contaminant, chlorinated solvents. Locating contaminants meant drilling many expensive wells. Removal involved costly excavation, with the potential of exposing workers and the environment to the waste, or decades of pump and treat operations, without assurance of meeting regulatory cleanup requirements.

TO-DAY

Over 50 new and innovative technologies that EM has demonstrated under the **Subsurface Contaminants Focus Area** are providing, in nearly 150 deployments, solutions to the dilemma of cost-effective soil and groundwater remediation.

Innovative thermal methods can mobilize and extract chlorinated solvents from the subsurface in months rather than decades. Enhanced bioremediation has enabled in situ destruction of organics at lower risk to workers and the environment and at lower cost than conventional ex situ methods. The improved reliability and performance of in situ reactive treatment barriers have been led to regulatory acceptance, thereby averting the need to excavate emplaced waste and the associated risks to workers and environment.

Characterization of the subsurface has been revolutionized through the application of oilfield technologies and near-real-time analytical field methods enabling more data and hence better decisions to be obtained quickly and cost-effectively on this billion-dollar problem.

Tomorrow

Enhancement of today's technologies will enable waste stabilization or destruction at greater depth and with more effective agents, and will enable caps, covers, and subsurface barriers to contain long-term radionuclides and meet regulatory requirements. In addition, cost-effective cleanup of contaminants in complex geologic structures and previously inaccessible areas, and long-term stewardship to ensure the persistence of acceptable cleanup levels, will be possible based on scientific advances in geophysics, geochemistry, bioremediation, and other fields.

Locating and Identifying Contaminants

Background

Remediating underground contamination takes accurate characterization of the source, composition, spread, and predicted pathways of contaminant plumes. Rotary and auger drilling techniques can spread the contamination from the surface or vadose zone down into the lower levels of the subsurface and groundwater.

Subsequent laboratory analysis is costly and time-consuming and generates additional waste materials. These considerations often limit the number of samples retrieved and analyzed, reducing the completeness and accuracy of site characterization.

In addition, ensuring that remediated sites remain safe requires placement and operation of inexpensive, yet very reliable, tools for long-term monitoring.

Energy Wave Drilling System

Safety, Performance

Resonant Sonic Drilling [#55]

- Works without drilling fluids to minimize contamination spread and waste generation.
- Provides excellent-quality, continuous core samples.
- Can cut through difficult soil strata that resist conventional drilling methods.
- Deployed at the Hanford and Savannah River sites and Idaho National Environmental Engineering Laboratory.

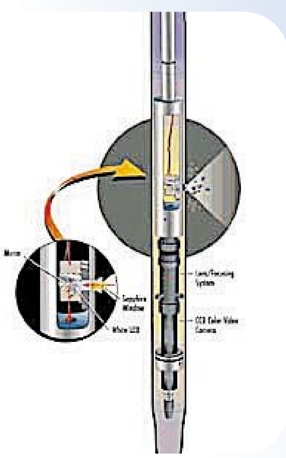
[#] indicates technology's OST/TMS ID number.

Hydraulic Push Sampling System

Cost, Performance

- Much faster and up to 60% less expensive than drilling—enables more samples and better characterization.
- Real-time results can be used immediately in the field to expedite measurement, remediation, and site monitoring activities.
- In situ analysis eliminates worker exposure to contaminants during sample collection, transport, and laboratory testing.
- Minimizes subsurface disturbance and secondary waste generation because no drilling fluids are required.
- Deployed with sensor technologies at many DOE sites.

Cone Penetrometer [#243]



A wide variety of sensor technologies can be used with the Cone Penetrometer.

- **Spectroscopy probe**–measures a broad range of chemicals including DNAPLs.
- **Video imaging probe**–acquires visual information about the subsurface.
- **Sampling probe**–brings monitoring samples to the surface via small-diameter tubes.
- **Permeability calculator**–determines the permeability of subsurface levels.

Containing and Treating Contaminants Underground

Background

Subsurface contaminants that have migrated to the groundwater are often dispersed over large areas up to hundreds of feet deep. Groundwater and soils contaminated with organic compounds, like certain solvents, are difficult to remediate. The baseline approach of pumping and then treating at the surface can take decades and still not remove all contamination. Pump-and-treat processes have high operation and maintenance costs and can increase the exposure of workers and the environment to hazardous chemicals.

In Situ Treatment Wall

Passive Reactive Barrier [#46]

Cost, Risk

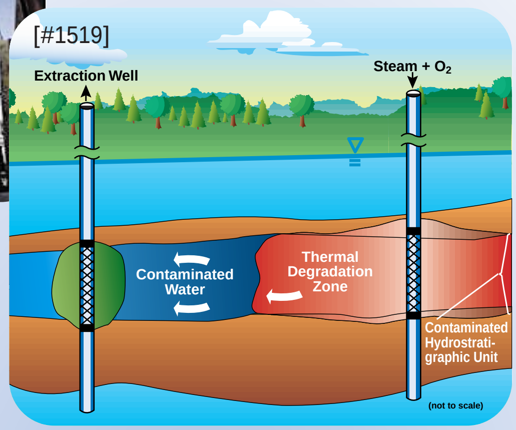
- Significantly reduces costs and risk by capturing and treating contaminant plumes underground.
- Protects surface water quality and generates less waste material for disposal.
- Over $100 million life-cycle cost savings projected from current deployments alone.
- Deployed at the Rocky Flats Environmental Technology Site, and Oak Ridge National Laboratory.

[#] indicates technology's OST/TMS ID number.

DNAPL Mobilization and Destruction (DUS/HPO)

Schedule, Cost

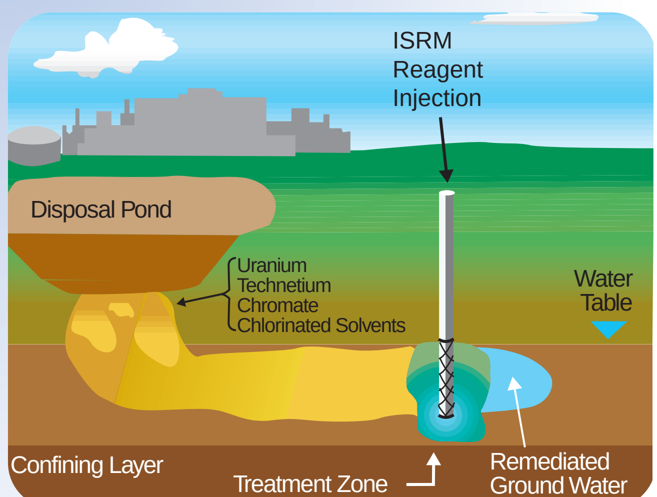
Dynamic Underground Stripping [#7] and Hydrous Pyrolysis/Oxidation [#1519]



- Enables rapid and cost-effective removal and destruction of DOE's most prevalent contaminant.
- Yields orders-of-magnitude increases in remediation rate.
- DUS mobilizes DNAPLs; HPO destroys them underground.
- Estimated cost savings to remediate identified DNAPL sources is up to $100 million.
- Deployed at Portsmouth.

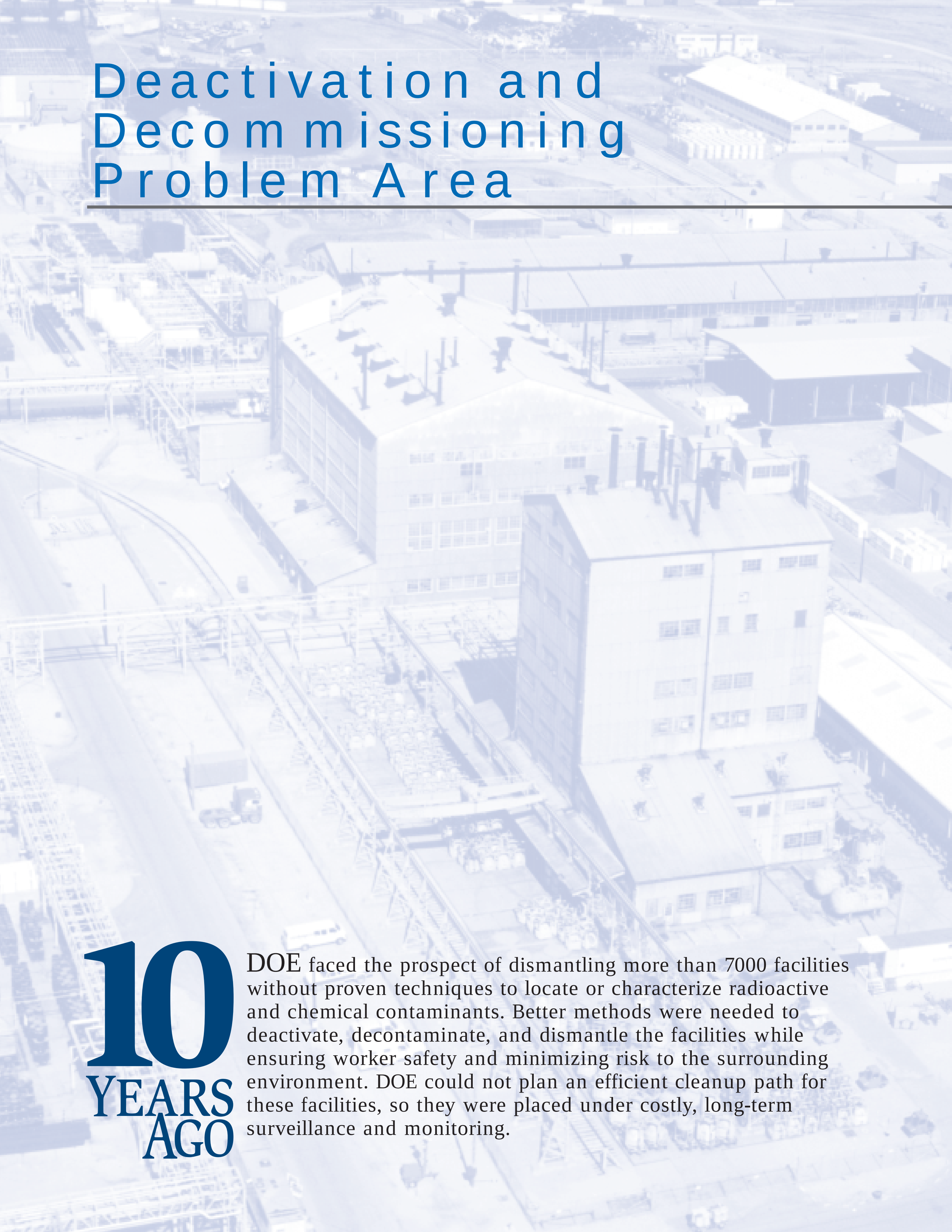
Groundwater Detoxifier

- Rapidly immobilizes or eliminates toxic and carcinogenic contaminants within an aquifer, and keeps on working.
- Costs up to 60% less than previous remediation methods.
- Works underground, increasing safety by reducing worker exposure to hazardous materials.
- Treats contaminants too deep for conventional trench-and-fill technologies.
- Deployed at the Hanford site.



Safety, Cost

In Situ Redox Manipulation [#15]



Deactivation and Decommissioning Problem Area

10 YEARS AGO

DOE faced the prospect of dismantling more than 7000 facilities without proven techniques to locate or characterize radioactive and chemical contaminants. Better methods were needed to deactivate, decontaminate, and dismantle the facilities while ensuring worker safety and minimizing risk to the surrounding environment. DOE could not plan an efficient cleanup path for these facilities, so they were placed under costly, long-term surveillance and monitoring.

TO-DAY

Seven EM large-scale demonstration and deployment projects conducted by the **Deactivation and Decommissioning Focus Area** at DOE sites have validated the improved performance of over 75 technologies for safe, cost-effective deactivation, decommissioning, and dismantlement of facilities. Most of the improved technologies have been adopted directly or adapted from the commercial nuclear power and other industries.

The results, through over 150 deployments, are improved protection of workers from radiation or chemical exposure and injury, more efficient work operation; and to achieve better performance in remediating buildings, underwater facilities, concrete pads, piping, and equipment.

Automated characterization methods with near-real-time data analysis can now replace former handheld devices requiring slow follow-on laboratory analysis. Improved cutting tools are being coupled with robotics technologies to increase productivity while reducing worker exposure. The effectiveness of new worker protection gear has been proven on the job.

The impact of these new technologies is significant—efficient dismantlement of the numerous plutonium-contaminated gloveboxes at the Rocky Flats site, reducing by 80% the footprint of the C-Reactor and supporting buildings at the Hanford site, and placing the reactor in interim storage.

Tomorrow

Remediation of facilities with higher radiation, thicker concrete, and high-explosive contamination will be accomplished both by adapting and proof-testing today's technologies and by using new technologies based on research in contaminant binding, surface chemistry, robotics, and other scientific areas.

Determining Location and Extent of Contamination in Facilities

Background

DOE has over 7000 facilities contaminated with radioactive and hazardous materials and chemicals like asbestos and lead. These facilities must be decontaminated before they can be dismantled or used for other activities.

Previous methods of locating, measuring, and documenting contamination relied on expensive, time-consuming, and sometimes unreliable laboratory tests. Workers had to spend long periods collecting samples in confined and often hazardous areas.

Contamination Mapping System

Surface Contamination Monitor [#1942]

Schedule, Performance

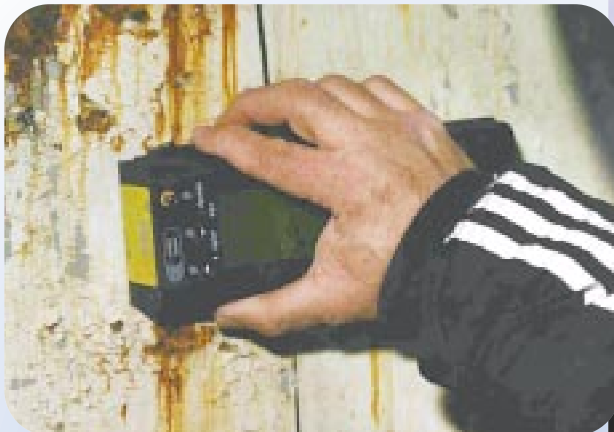
- Produces more timely, consistent, and reliable contamination maps.
- Provides real-time imagery and delivers results up to 10 times faster than conventional instruments.
- Automatically generates rigorous documentation reports to meet free-release requirements.
- At the Nevada Test Site, surveyed and documented an area the size of six football fields in days instead of months.
- Deployed at many DOE sites.

[#] indicates technology's OST/TMS ID number.

Instant Contamination Analyzer

- Delivers results on RCRA contamination fast—in seconds instead of months.
- Enables managers to make immediate decisions on remediation steps.
- Eliminates sample-handling errors and waiting time for analysis from laboratories.
- Pays for itself in less than 20 samples.
- Deployed at the Idaho National Environmental Engineering Laboratory.

Schedule, Cost



Lead Paint Analyzer [#2317]

Performance, Safety

Remote Underwater Characterization System [#2151]

Submersible Measurement System

- Delivers more complete characterization with improved worker safety.
- Operates in confined spaces in spent fuel pools and underwater reactors.
- Transports cameras and radiation sensors to places previously inaccessible.
- Remotely-operated—requires fewer workers in hazardous areas during characterization activities.
- Deployed at the Idaho National Environmental Engineering Laboratory.

DISMANTLEMENT/WORKER SAFETY

BACKGROUND

Surplus DOE facilities with radioactive and hazardous contamination span the range of construction components from concrete block to structural steel to massive cast-in-place, steel-reinforced concrete. They often contain large amounts of steel piping and equipment. As long as these aging structures remain contaminated and in place, they require expensive and sometimes hazardous maintenance and surveillance activities.

Dismantlement and removal of radioactive and contaminated materials can be a long, labor-intensive process with high potential for worker exposure, heat stress, and injury.

Superior Cutting Torch

Oxy-Gasoline Torch [#1847]

Schedule, Cost

- Up to four times faster and 30% cheaper than baseline cutting system.
- Uses readily available, less expensive fuel.
- Makes cleaner cuts and works well on rusty surfaces.
- One of DOE's most-deployed technologies—now used extensively at six sites.

[#] indicates technology's OST/TMS ID number.

Remote Diamond Wire Saw

- Safely and cost-effectively segments complex metal structures such as reactors, heat exchangers, and tanks.
- Remote operation provides significant reduction in personnel exposure to highly contaminated and radioactive materials.
- Cuts segmentation costs by over one-third compared to plasma cutting.

Schedule, Safety

Diamond Wire Saw Cutting of Large Metal Objects [#2389]

Schedule, Cost

Remote Concrete Demolition System [#2100]

Remotely-operated Demolition System

- Accomplishes concrete demolition tasks in days instead of months.
- Greatly reduces worker fatigue and exposure to contaminants and industrial hazards.
- Can perform in very tight areas with limited access.
- Deployed at Argonne National Laboratory and Idaho National Environmental Engineering Laboratory.

Schedule, Safety

Lightweight Cooling System

- Greatly increases productivity of workers wearing protective equipment in hot environments.
- The higher the temperature, the greater the increases in stay-time and productivity.
- Protects workers from heat stress.
- Deployed at many DOE sites.

Personal Ice Cooling System [#1898]

Mixed, Low-Level, and Transuranic Waste Problem Area

10 YEARS AGO

Almost 170,000 cubic meters of mixed low-level (MLLW) and transuranic waste was stored throughout the DOE complex with few available options for characterization, treatment, and disposal. Technologies did not exist for effective characterization of transuranic waste, which would prevent certification of shipments to the disposal site under construction—the Waste Isolation Pilot Plant (WIPP).

TO-DAY

With treatment technologies identified or developed through the **Mixed Waste Focus Area**, thermal and nonthermal alternatives are readily available for the treatment of more than 90% of DOE's MLLW. Separation and stabilization technologies for heavy metals such as mercury have been demonstrated and are available from commercial vendors. Despite significantly more stringent off-gas control and monitoring requirements, DOE incinerators are still operating, thanks to innovative technologies and operational controls tailored to ensure compliance.

Virtually all contact-handled transuranic waste stored in drums in the DOE complex can be effectively characterized by nondestructive examination and assay systems at DOE sites and by private sector vendors. Site characterization systems have been evaluated with performance demonstration programs, and several sites have been certified to ship waste to WIPP. In addition, commercial nondestructive examination and assay systems have been demonstrated, and comparative analysis has been performed to provide sites and vendors objective data on system performance against a variety of surrogate and real waste materials.

Tomorrow

Resolution of the most challenging mixed waste issues, involving large equipment and packages and remote-handled wastes with very high radiation fields, will be possible with new technologies from research and development in surface chemistry, spectroscopy, oxidation processes, and other areas.

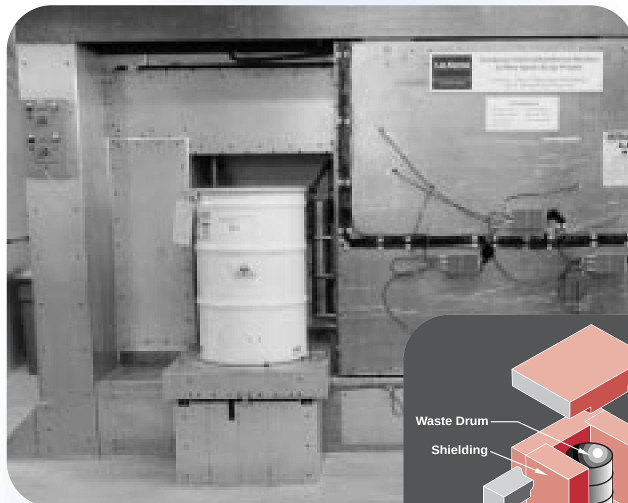
Characterizing Mixed Waste in Drums

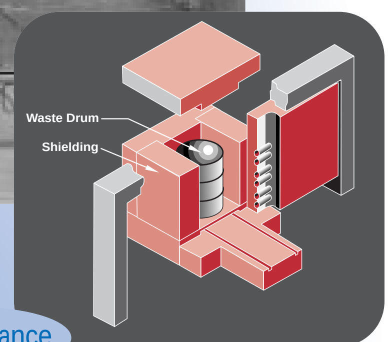
Background

Hundreds of thousands of drums containing mixed low-level and transuranic waste are in storage at more than 20 sites across the DOE complex. Before this waste can be shipped to appropriate disposal facilities, each container must be characterized to ensure it meets applicable waste acceptance criteria.

Significant characterization problems arise from variations in materials, levels of contamination, and the volume of material in each drum. Previous non-invasive scanning systems could certify only about half of the drums, and opening drums for manual inspection would cause unacceptable cost, schedule, and worker safety consequences.

High-Sensitivity Assay





Combined Thermal/Epithermal Neutron (CTEN) Waste Assay [#1568]

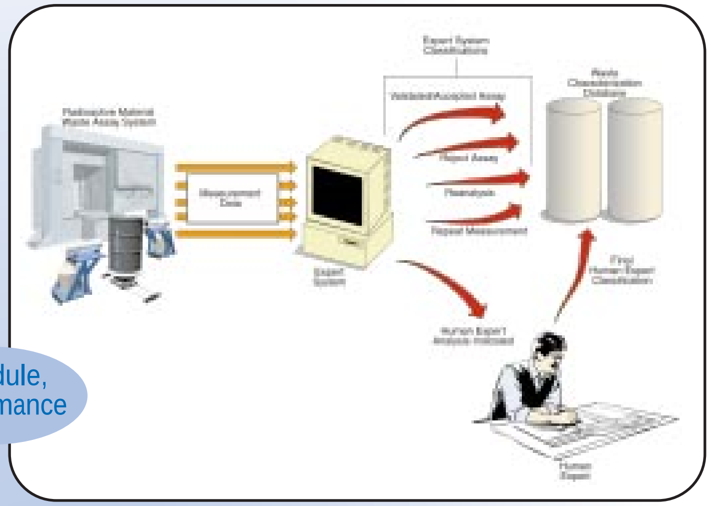
Performance

- Enables shipment and disposal of most contact-handled waste drums.
- Allows certification of many drums that cannot be certified by any other technique.
- Meets certification requirements for disposal of many common waste forms at the Waste Isolation Pilot Plant.
- Deployed at Los Alamos National Laboratory.

[#] indicates technology's OST/TMS ID number.

Automated Data Validation

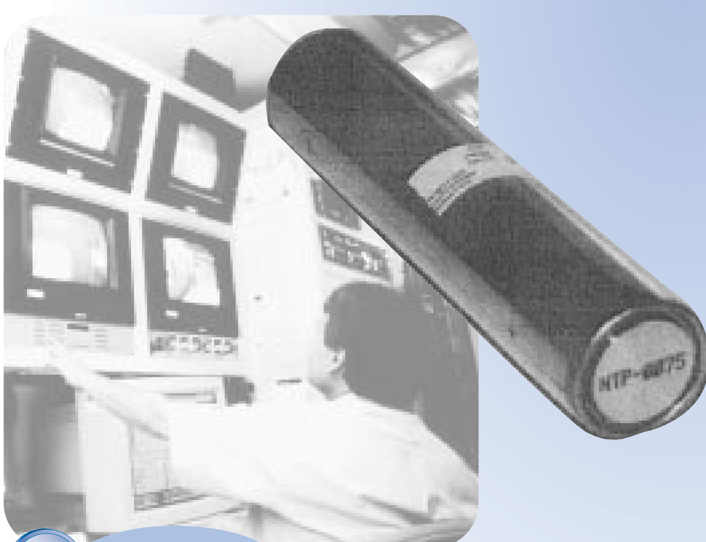
- Substantially reduces routine manual review of thousands of data packages.
- Provides faster turnaround and cuts staffing requirements.
- Makes complex decisions quickly with minimal operator oversight.



Schedule, Performance

Expert System for Non-Destructive Assay Data Validation [#2233]

Assay System Testing Standards



Performance, Risk

NDA Support of the CAO's Performance Demonstration Program for WIPP [#2017]

- Ensures that radioassay characterization systems are providing valid data.
- Provides precise blend of nuclear materials for system testing.
- Helps troubleshoot system hardware problems and requalify system performance after hardware or software changes.
- Deployed at many DOE sites.

Mixed Waste Stabilization

Background

Cement grout is used to stabilize much of the sludge, soils, and homogeneous solids in DOE's mixed low-level waste, but some materials contain high concentrations of salts, like nitrates, chlorides, and sulfates. These salts interfere with the performance of the cement, causing setup failures or deterioration of the waste form over time. Mixing very low proportions of waste material with the cement improves the performance, but significantly increases waste volume.

DOE also has large quantities of solid contaminated waste, such as lead and debris, that cannot be sufficiently immobilized without greatly limiting the amount of waste material in each container. Lower waste loadings multiply waste handling and transportation costs and consume scarce disposal capacity.

Small-Particle Waste Immobilizer

Polymer Microencapsulation [#166]

Performance, Cost

- Produces a waste form that sets up quickly and doesn't deteriorate over time.
- Generates less disposal volume than previous methods.
- Reduces the risk to human health and the environment.
- Used to treat waste from Idaho National Environmental Engineering Laboratory.

[#] indicates technology's OST/TMS ID number.

Lead and Debris Stabilizer

Polymer Macroencapsulation [#30]

BLUE CHIP TECHNOLOGY Performance, Cost

- Surrounds wastes and isolates contaminants from the environment.
- Avoids the expensive capital cost and secondary waste involved in thermal treatment.
- Enables greater waste loading in each container, reducing handling, transporting, and disposal costs.
- Named *Best Demonstrated Available Technology* for radioactive lead soils and mixed waste debris by the EPA.
- Has been used for disposal of radioactive lead from many DOE sites.

Additional information about the OST program and individual technologies is available on the Internet.

Office of Science and Technology

http://ost.em.doe.gov

Program Information

Technology Management System

detailed on-line information on all OST technologies

Publications

Innovative Technology Summary Reports

Focus Area Annual Reports

Success Stories

Deployment Information

Environmental Management Science Program

http://emsp.em.doe.gov

Focus Areas

Deactivation and Decommissioning	www.netl.doe.gov/dd
Mixed Waste	http://wastenot.inel.gov/mwfa
Subsurface Contaminants	http://www.envnet.org/scfa
Tanks	http://www.pnl.gov/tfa